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Sea Scallop Research

Hudson Canyon TAC

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Project Title: **Comparison of habitats supporting high and low sea scallop, *Placopecten magellanicus*, densities on Georges Bank.**

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1. Project Summary

Objectives: We compared habitats that support high densities of scallops with adjacent areas that appear to support low densities of scallops. We examined scallop abundance, size and spatial distribution and associated macroinvertebrate benthic community and substrate in unsurveyed areas of the Great South Channel.

Methodology: We conducted two video surveys in the Great South Channel. The sampling procedure for these surveys was a multistage design with stations separated by 0.85 nautical miles, similar to the 1999/2000/2001/2002 SMAST surveys. These surveys produced a series of maps of the sea floor detailing the distribution of substrate, depth, live scallops, dead scallops, and macroinvertebrates (sponges, starfish, filamentous fauna). We expanded the analysis of the data collected during the video surveys applying GIS software and spatial analysis to compare areas of low and high scallop density.

Conclusions:

1. The USGS sediment data used in Amendments 10 and 13 misidentified the sediment distribution and proportions present in the Great South Channel.
2. The presents of granule/pebble substrate does not necessarily indicate a high density of scallops.
3. How substrate is distributed may be as important as the quantities of different sediment types in determining benthic community structure.

Rationale: The research completed under this grant, coupled with our ongoing work, has the potential to redefine proposed habitat HAPCs and MPAs while limiting the conflict between the habitat interests and the sea scallop fishery. In support of the development of Framework 16/39, we presented preliminary sediment, scallop, starfish and macroinvertebrate maps to the NEFMC sea scallop PDT on 4th Dec 2003. In support of the 39th Northeast Regional Stock Assessment Workshop on sea scallops, the sea scallop number and shell height raw data for the entire SMAST database (1999-2003) were provided to the NMFS to assist in the stock assessment analyses (emailed to Dr Paul Rago on 3/31/2004). The paper Stokesbury et al. 2004 was provide to the Invertebrate Subcommittee Chair and placed on the NMFS website as a support document for the 39th SARC on scallops. The video survey techniques and data were also reviewed and discussed at meetings of the NMFS Invertebrate Subcommittee in conjunction with the NMFS scallop survey. The NEFMC has received these data as well (email from T. Hill 5/25/2004). We discussed our data base and Habitat research at the Essential Fish Habitat Omnibus Amendment Scoping meeting on 10th March 2004 with the chairs of the Habitat Oversight Committee and the Habitat PDT, and with the Essential fish Habitat working group (4 Jan 2005). We presented our video survey and habitat research at the Annual ICES meeting in Vigo, Spain and the AAAS in Washington, D.C.

2. Description of the issue/problem

Project goals and objectives: We compared habitats that support high densities of scallops with adjacent areas that appear to support low densities of scallops. We examined scallop abundance, size and spatial distribution and associated macroinvertebrate benthic community and substrate in unsurveyed areas of the Great South Channel.

The problem addressed: The New England Fisheries Management Council and the National Marine Fisheries Service have implemented Amendments 10 and 13 for sea scallop and groundfish management, respectively. Both of these management plans contain a series of alternatives to protect essential fish habitat. Five habitat metrics are used to assess these different alternatives; these are sediment, essential fish habitat, guild, aggregation and bottom-dwelling species. In many cases the data used for these metrics is sparse, for example the sediment data are based on Poppe et al. 1989 which had a grab sampling frequency of approximately 1 sample every 100 nm^2. The SMAST video surveys have focused on the historic aggregations of Georges Bank since 1999. The sediment maps generated from these surveys have been presented to the NEFMC Habitat Technical Team. However these maps only examine areas of historically high densities of scallops. Sea scallops prefer a sand/granule/pebble substrate. The substrate believed to be of primary importance for juvenile groundfish are cobble/boulder substrates that support biologically complex habitat made up of sessile and encrusting invertebrates. Although the SMAST maps are very useful in describing the sea floor in scallop grounds they do not presently provide information on the types of habitat outside the scallop grounds. By mapping and comparing areas of low and high scallop densities we will be able to determine what physical and biological variables are associated with sea scallop aggregations and which areas may provide the best essential fish habitat.

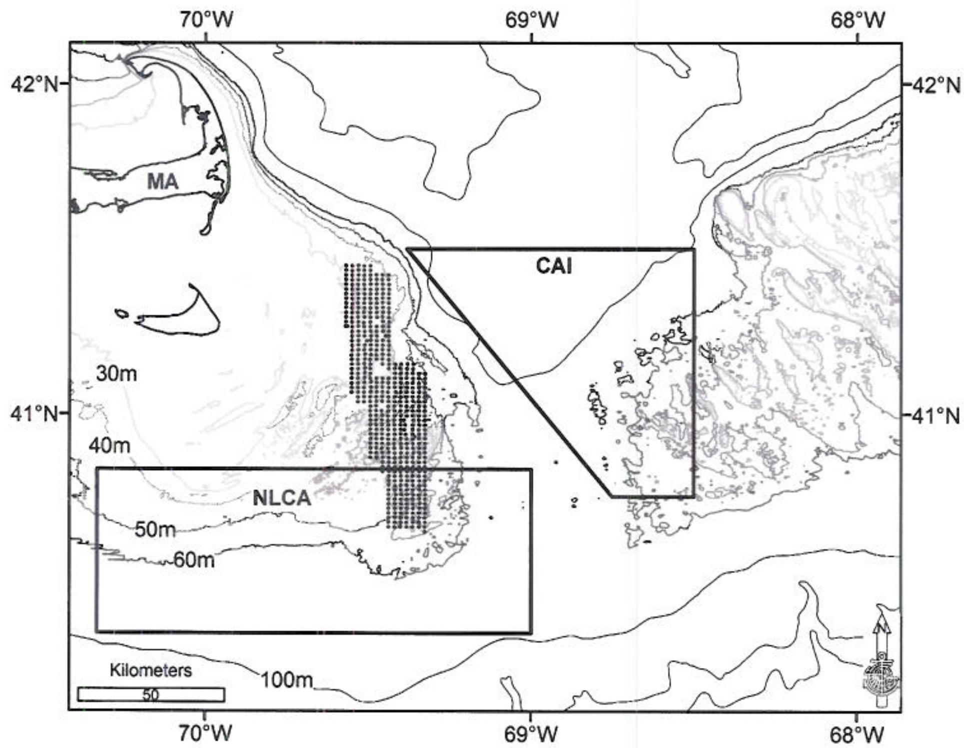
3. Approach

We surveyed the Great South Channel Western with the F/V Huntress 5^{th} to 11^{th} May 2004 and the F/V *Liberty* from the 15^{th} to the 19^{th} May 2004 (which also surveyed some of the Nantucket Lightship Area under NOAA EA 133F-03-CN-0051) (Fig. 1).

A centric systematic sampling design positioning stations on a 1.57 km grid, with four quadrats sampled at each station, was used to survey this area. The precision of this survey design ranged from 5 to 15 % for the normal and negative binomial distributions, respectively, for sea scallop densities assessed in the NLCA in 1999 (Stokesbury 2002).

The sampling pyramid was deployed from scallop fishing vessels (Stokesbury 2002; Stokesbury et al. 2004). Two downward looking cameras provided 3.235 m^2 and 0.8 m^2 views of the sea floor. A third camera provided a profile view of the sea floor. It was possible to identify different taxonomic categories to a minimal size of about 40 mm. All fish and macroinverebrates were counted including those along the edge of the quadrat image that were only partially visible. To correct for this edge effect 75 mm, based on the average shell height of the scallops observed, was added to each edge of the quadrat image providing quadrat size 3.235 m^2 (Stokesbury 2002; Stokesbury et al. 2004).

Figure 1. Map of the survey stations completed during May 2005 examining the habitat in the western portion of the Great South Channel.



A mobile studio, including monitors and S-VHS video recorders for each camera, a monitor for the Captain controlling the vessel's hydraulic winches to deploy the pyramid, a laptop computer with Arcpad GIS® software integrated with a differential global positioning system and WAAS receiver, and a laptop computer for data entry, was assembled in the wheelhouse. The survey grid was plotted prior to the cruise in Arcpad GIS®. Two scientists, a captain, mate and one deck-hand were able to survey about 100 stations every 24 hours. Four quadrats observed at each station increased the sample area to 12.94 m^2.

Video footage of the sea floor was recorded on S-VHS tapes. For each quadrat, the time, depth, and latitude and longitude were recorded.

Data Analysis

After each survey the videotapes were reviewed in the laboratory and a still image of each quadrat was digitized and saved using Image Pro Plus® software (TIF file format). Within each quadrat, epifaunal macroinvertebrates and fish were counted and the substrate was identified (Stokesbury 2002; Stokesbury et al. 2004). When possible fish and macroinvertebrates were identified to species, otherwise animals were grouped into categories based on taxonomic orders. Unidentified fish were grouped as "other fish." Counts were standardized to individuals m^{-2}. For the sponges, hydrozoa/bryozoa, and sanddollar categories, if one organism was observed the quadrat was given a value of one.

Mean densities and standard errors of macroinvertebrates were calculated using equations for a two-stage sampling design (Cochran 1977):
The mean of the total sample is:

$$\bar{\bar{x}} = \sum_{i=1}^{n} \left(\frac{\bar{x}_i}{n} \right) \tag{1}$$

where:
n = primary sample units (stations)
$\bar{x}_i$ = sample mean per element (quadrat) in primary unit i (stations)
$\bar{\bar{x}}$ = the mean over the two-stages

The standard error of this mean is:

$$S.E.(\bar{x}) = \sqrt{\frac{1}{n}(s^2)} \tag{2}$$

where:
$s^2 = \sum^{n} (\bar{x}_i - \bar{\bar{x}})^2 / (n-1)$ = variance among primary unit (stations) means.

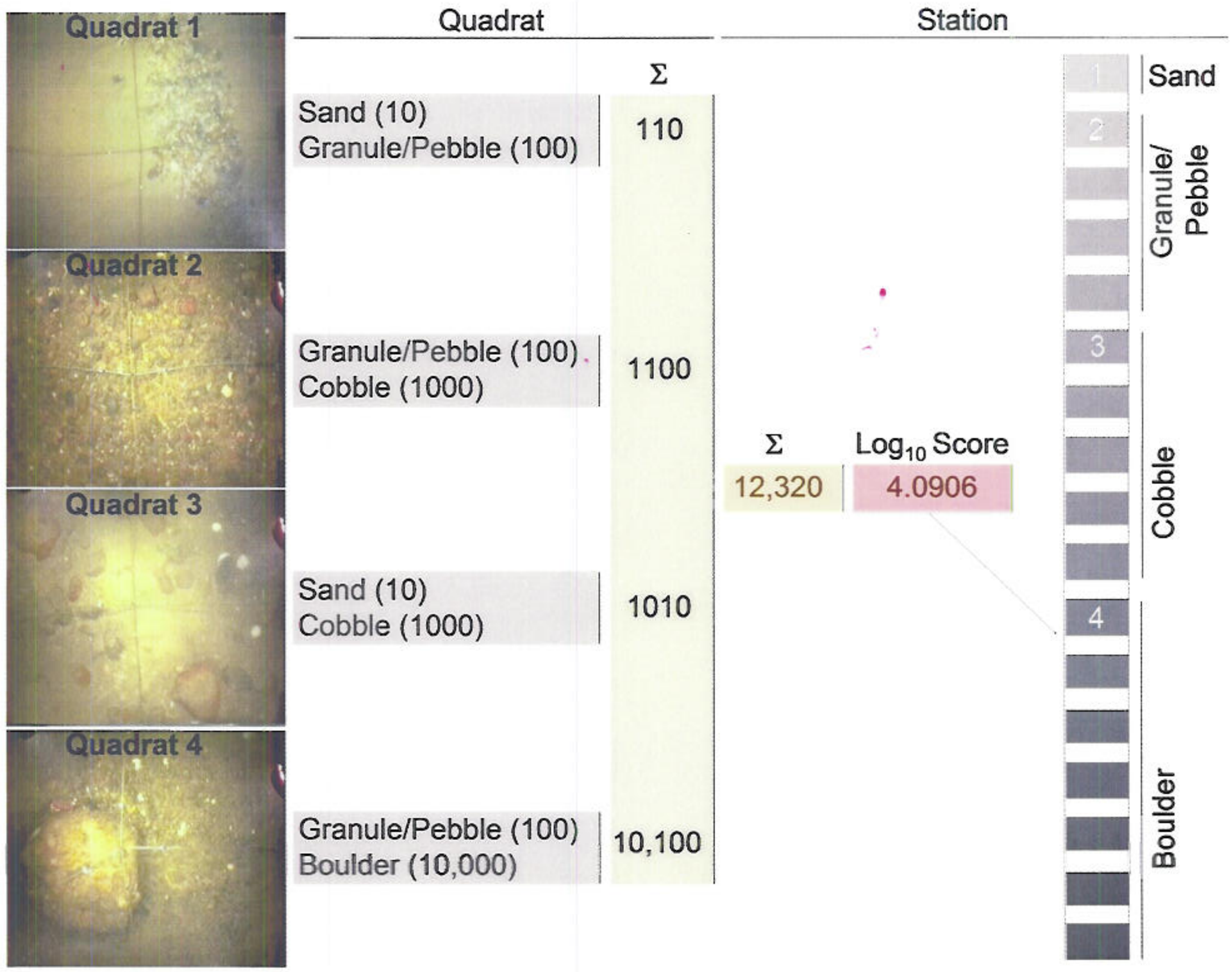
As the sampling fractions were small, hundreds of scallops sampled compared to millions of scallops in the area, so the finite population corrections were omitted simplifying the estimation of the standard error (Cochran 1977). The 95% confidence intervals were calculated using $\bar{\bar{x}} \pm t_{\alpha}S.E.(\bar{\bar{x}})$ (Cochran 1977).

Sediments were visually identified in the digitized images, following the Wentworth particle grade scale, where the sediment particle size categories are based on a fixed reference point of 1 mm; sand = 0.0625 to 2.0 mm, gravel = 2.0 to 256.0 mm and boulders > 256.0 mm. Gravel was divided into three categories, granules = 2.0 to 4.0 mm, pebbles = 4.0 to 64.0 mm, and cobble = 64.0 to 256.0 mm. Shell debris was also identified.

For NOAA grant NOAA EA 133F-03-CN-0051 we devised a procedure that allows all the information from the four quadrats at each station to be compiled and represented in a graduated scale, which we employ here. Quadrats are categorized by the presence or absence of sand, granule/pebble, cobble or boulder substrates. Substrates are scored by quadrat with sand = 10, granule/pebble = 100, cobble = 1000, and boulder = 10,000. The four quadrat scores are summed to provide a station substrate score. The station substrate score is $\log_{10}$ transformed. Substrates at each station are mapped by $\log_{10}$ substrate score, which provides an index of station-level substrate complexity while preserving the substrate information at the quadrat-level (Fig. 2).

Figure 2. Substrates are scored by quadrat with sand = 10, granule/pebble = 100, cobble = 1000, and boulder = 10,000. The four quadrat scores are summed to provide a station substrate score (12,320). The station substrate score is $\log_{10}$ transformed (4.0906). The station $\log_{10}$ substrate score provides an index of substrate complexity while preserving the substrate information at the quadrat-level. For example, $10^{4.0906} = 12{,}320$ which indicates 1 quadrat had boulder, 2 had cobble, 3 had granule/pebble, and 2 had sand substrates.

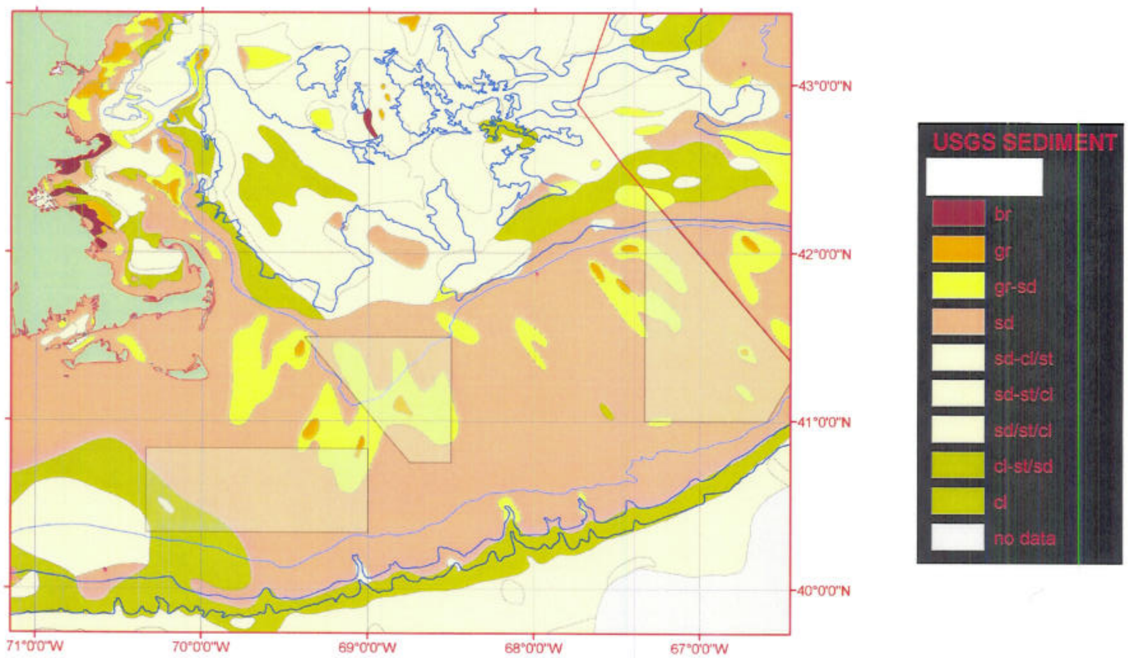
Substrate Classification Scheme



Results

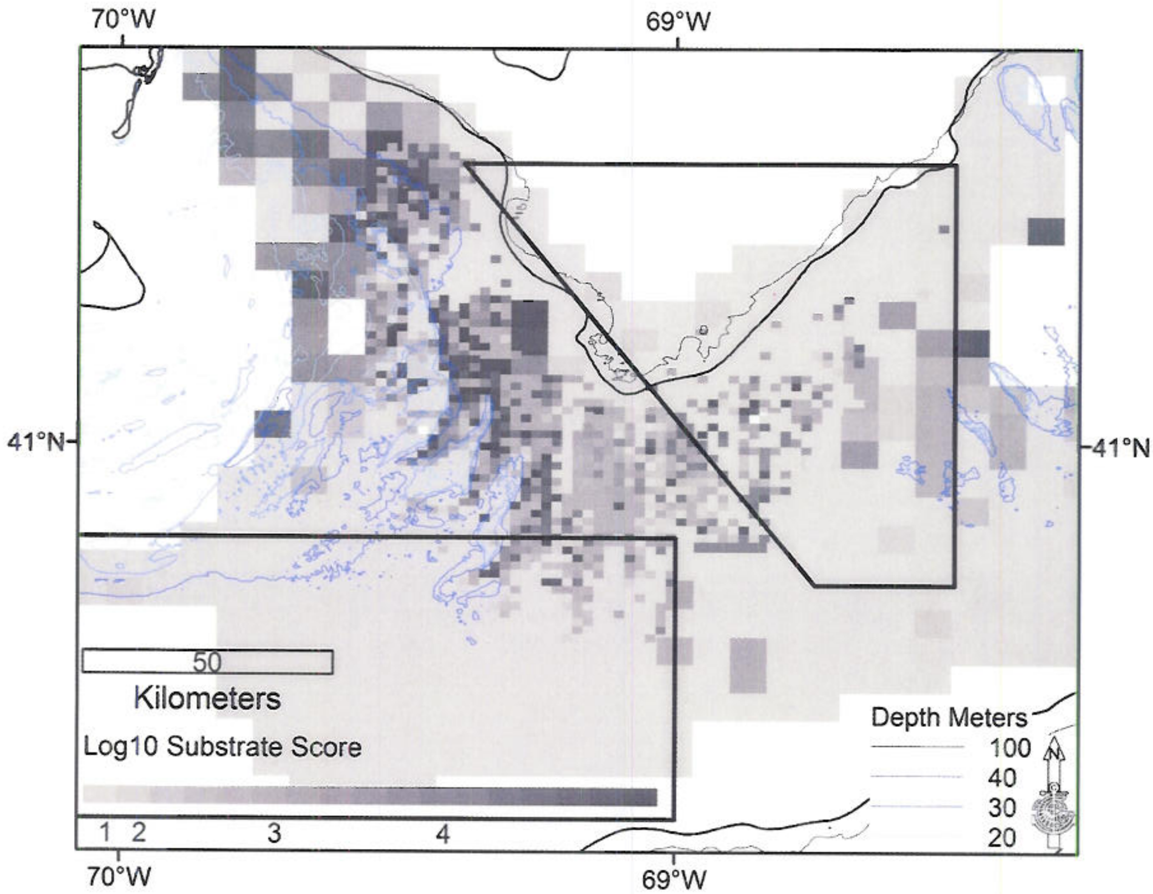
The USGS data compiled by Poppe et al. (1989) in based on approximately 1 grab sample every 100 nm^2 and appears to be a combination of several data sources, although we have had difficulty reproducing the sample locations presented in Amendment 10, page 93 (Fig. 3). In any case the spatial resolution is low and grab samples are limited as they generally do not sample sediment particles larger than granules effectively, pebbles frequently jam the doors of the grab and for larger cobble and boulders the grab can not be used (author's personal experience with grab samples during the EPA/NOAA EMAP South Carolinian Sampling program 1994-95). Thus the overall distribution of fine sediments is limited and the distribution of large particles is non-existent. These large sediments are of primary concern as they are more stable and support plant like animals which increase biocomplexity (Auster and Langton 1999).

Figure 3. The sediment map presently used by the NEFMC to assess the different habitat alternativies in Amendments 10 and 13; sampling frequency is approximately 1 grab sample every 100 nm^2. (Poppe et al 1989, Map 33 on page 93, in Amendment 10)



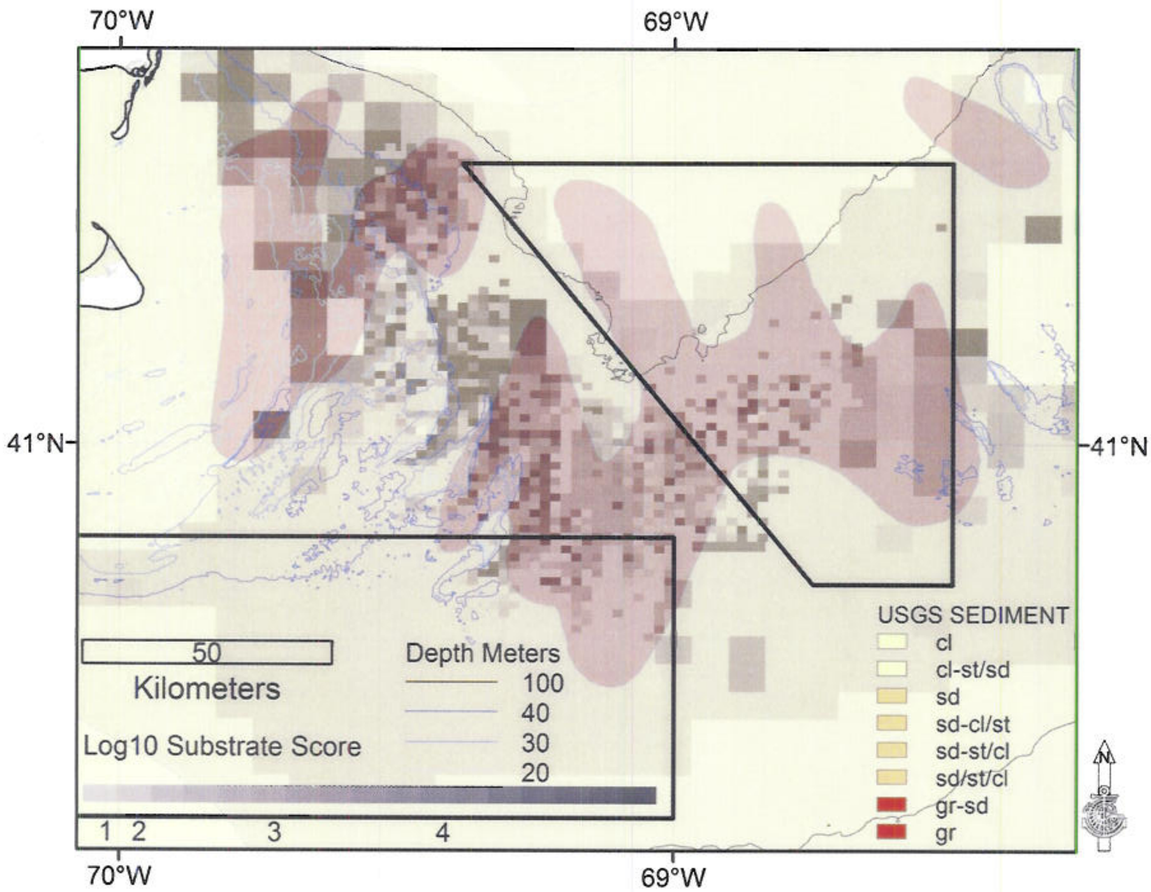
With the SMAST data collected on this research project and previous surveys at both the 1.6 and 5.5 km scale, the distribution of sediment in the Great South Channel becomes much clearer and starts to relate to the topography of the area (Fig 4). The strong currents in the area appear to produce a series of large sand dunes with granules/pebbles, cobble and boulders between them. This pattern dissipates to the east, in the deeper water of the Great South Channel and in the south as the current fans out into the Nantucket Lightship Closed Area.

Figure 4. The sediment composition from the SMAST video surveys for the Great South Channel of Georges Bank. The data from four quadrats was combined to represent the station each station represents 31km^2 and the finer 2.4 km^2 scales. Substrates are scored by quadrat with sand = 10, granule/pebble = 100, cobble = 1000, and boulder = 10,000, summed and $\log_{10}$ transformed, thus 1 = sand, while a value near 5 indicates that all four substrates were observed in each of the 4 quadrats.



Overlaying the SMAST data (Fig. 4) on the original Poppe et al (1989) map (Fig. 3) details the improvement in sediment composition information. Many areas were mis-identified due to limited spatial resolution and number of samples in the Poppe et al. map (Fig. 5).

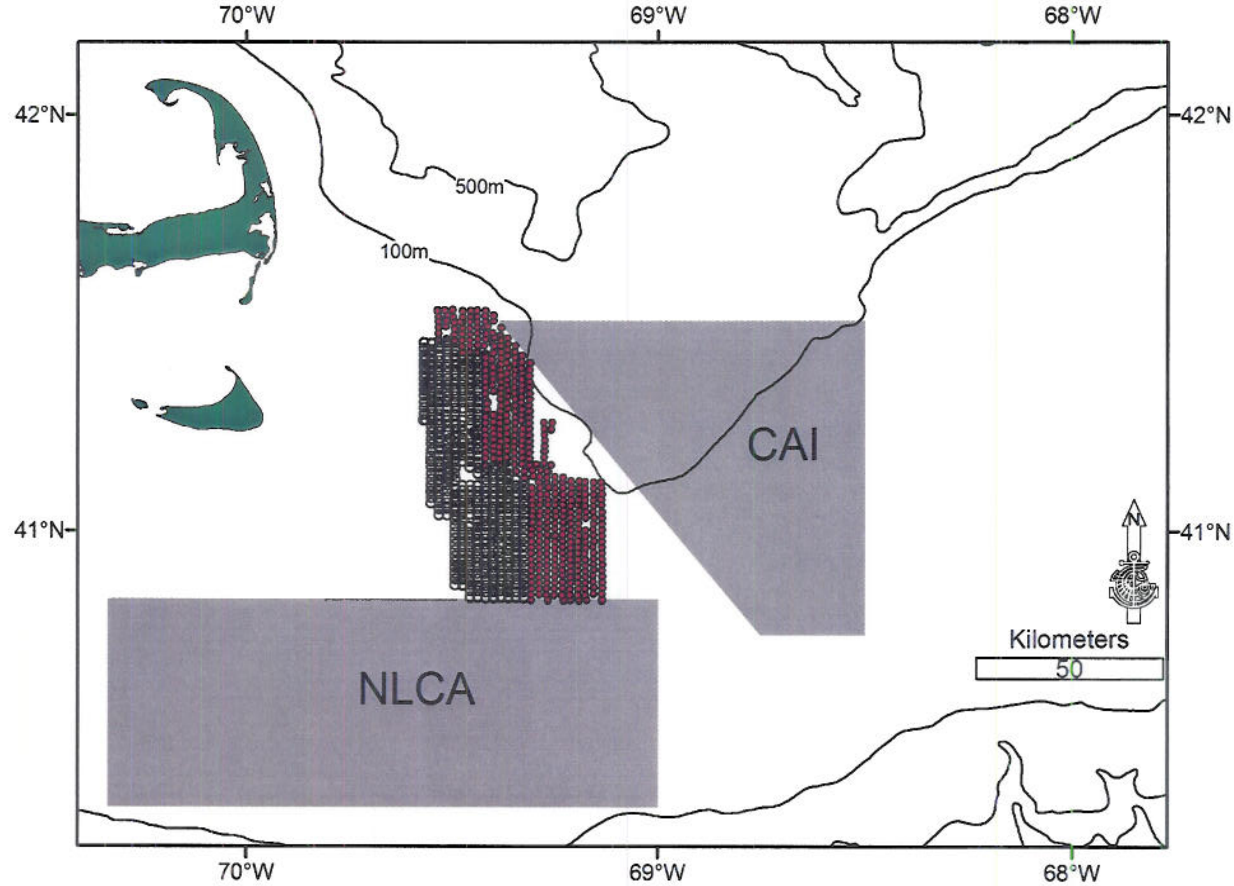
Figure 5. The sediment map presently used by the NEFMC to assess the different habitat alternativies in Amendments 10 and 13, sampling frequency is approximately 1 grab sample every 100 nm^2. (Poppe et al 1989, Map 33, in Amendment 10) with the SMAST video surveys (four quadrats per 31km^2 and 2.4 km^2 scale) overlaid.



Comparison of Sediment and Benthic community Structure.

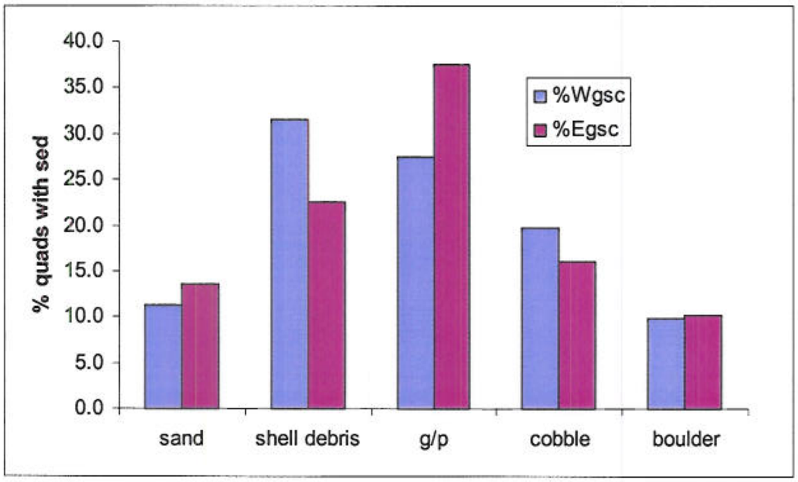
Stations observed in previous SMAST video surveys in the Eastern Great South Channel (EGSC), where scallops are abundant, were compared to those collected during this research project in the Western Great South Channel (WGSC) where, according to fishermen, sea scallops are rare (Fig 6).

Figure 6. SMAST stations sampled in the Great South Channel used in the comparing areas of low and high scallop densities; stations in black were sampled under this research program in the western portion (WGSC, 394 stations) where few scallops occur, station in red were sampled in 2001 and 2002 in the eastern portion (EGSC, 314 stations) where scallops are plentiful.



Significantly more granule/pebble substrate was observed in the EGSC than in the WGSC which was dominated by shell debris ($\chi^2 = 59.6$, df = 4, $p < 0.0001$). Cobble was also more abundant in the western portion of the Great South Channel, but the amount of boulders observed was similar (Fig 7). The percent similarity index for the substrate between these to areas was 87.3% suggesting that although the sediment make-up was different, the differences were not extreme.

Figure 7. Sediment composition for the Western and Eastern portions of the Great South Channel, g/p = granule/pebbles.



The fish and macroinvertebrates which make up the benthic community also differed between the West and Eastern portions of the Great South Channel. As fishermen suggested, the most striking difference was the density of scallops, in the EGSC we observed 2429 scallops in 1725 quadrats while in the WGSC we observed 201 scallops in 1576 scallops. The density of scallops differed significantly at 0.443 and 0.039 ind m^2 in the EGSC and WGSC, respectively (t-test, $t = 5.450$, $df = 706$, $p<0.001$, power 0.050:1.000) (Figs. 8 and 9). In the WGSC, Bryozoa/hydrazoa were the most frequently observed invertebrates while sea scallops dominated the Eastern portion (Fig 8 A).

The composition of the fish and macroinvertebrates in these two areas differ even with sea scallops removed from the analyses. The percent similarity for the benthic fauna was 70.4%, lower than that observed for the sediments. Bryozoa/hydrazoa and starfish dominated in the WGSC and EGSC, respectively (Fig 8B).

Although there was more granule/pebble in the EGSC the much higher density of scallops suggests that more than just sediment distribution contributes to these densities. Of the quadrats observed in the EGSC, 37.5% contained granule/pebble substrate and 38.4% contained scallops. Of the quadrats observed in the WGSC, 27.5% contained granule/pebble substrate and 7.2% contained scallops. The densities of fish and macroinvertebrates (with scallops removed from the data set) appear similar between areas, except for starfish and Bryozoa/hydrozoa (Fig 9. B).

Our analyses raise the interesting question "Why are scallops less abundant in the WGSC compared to the EGSC?"

One possibility is that water temperature, which is related to depth, increases above the lethal limit for scallops. The WGSC had an average water depth of 51.3 m compared to 87.6 m in the EGSC. However, if high water temperatures caused scallop mortality in this area, than we would expect scallops to be extremely rare. This was not the case; rather the density of scallops was similar to other macroinvertebrates in the WGSC (Figs. 8 B and 9 B).

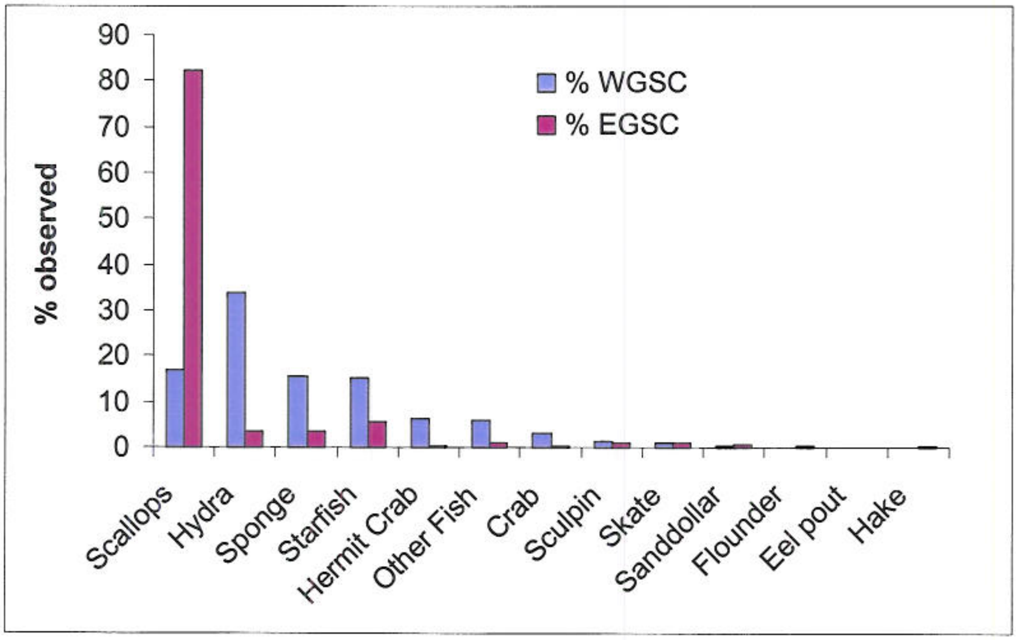
A hypothesis that possibly explains our observations is that the distribution of sediments on the sea floor, rather than the simple proportion, determines the density of scallops. For example, gravel (granule/pebble) substratum, filamentous flora and fauna and low decapod predations were critical factors determining scallop aggregation location in the Daie Des Chaleurs, Quebec, Canada (Stokesbury and Himmelman 1995). Homogeneous sand in areas of strong current flow and high decapod predation caused increase movement in sea scallops (Stokesbury and Himmelman 1996). The high currents in the western portion of the Great South Channel appear to create and possibly shift large sand dunes. The currents also aggregated the distribution of granule/pebble, cobble and boulders in the troughs of the sand dunes. This may concentrate the area that scallops can live as well as predator densities, such as decapods and fish (i.e. the Atlantic wolffish). Therefore, although the proportions of sediment types in the EGSC and WEGS are not extremely different, the sediment distributions may differ for example, create an oasis between the large sand dunes, but also greatly increase the frequency of encounter with predators. This could limit the abundance of sea scallops in the western portion of the Great South Channel, however, this is only a hypothesis and further observation and experimentation is required to test it.

Conclusions

4. The USGS sediment data used in Amendments 10 and 13 misidentified the sediment distribution and proportions present in the Great South Channel.
5. The presents of granule/pebble substrate does not necessarily indicate a high density of scallops.
6. How substrate is distributed may be as important as the quantities of different sediment types in determining benthic community structure.

Figure 8. Percentages of fauna observed in the Western and Eastern portions of the Great South Channel, A) all species observed, B) sea scallops excluded.

A)



B)

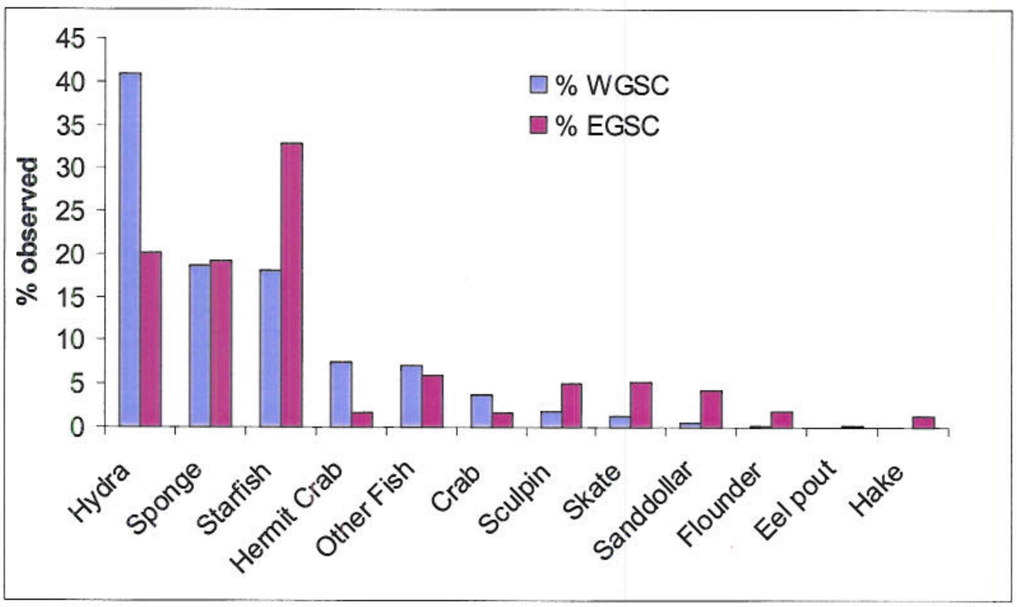
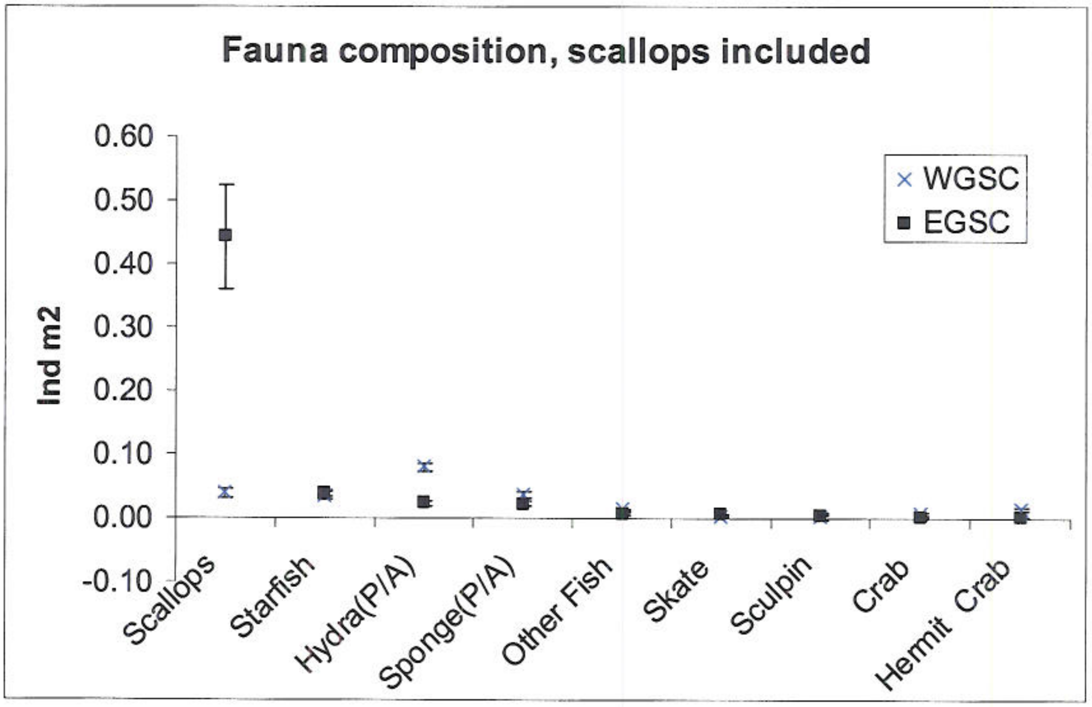


Figure 9. Mean densities and standard errors (bars) of fish and macroinvertebrates observed in the Eastern and Western portions of the Great South Channel, A) all species observed, B) sea scallops excluded.

A)



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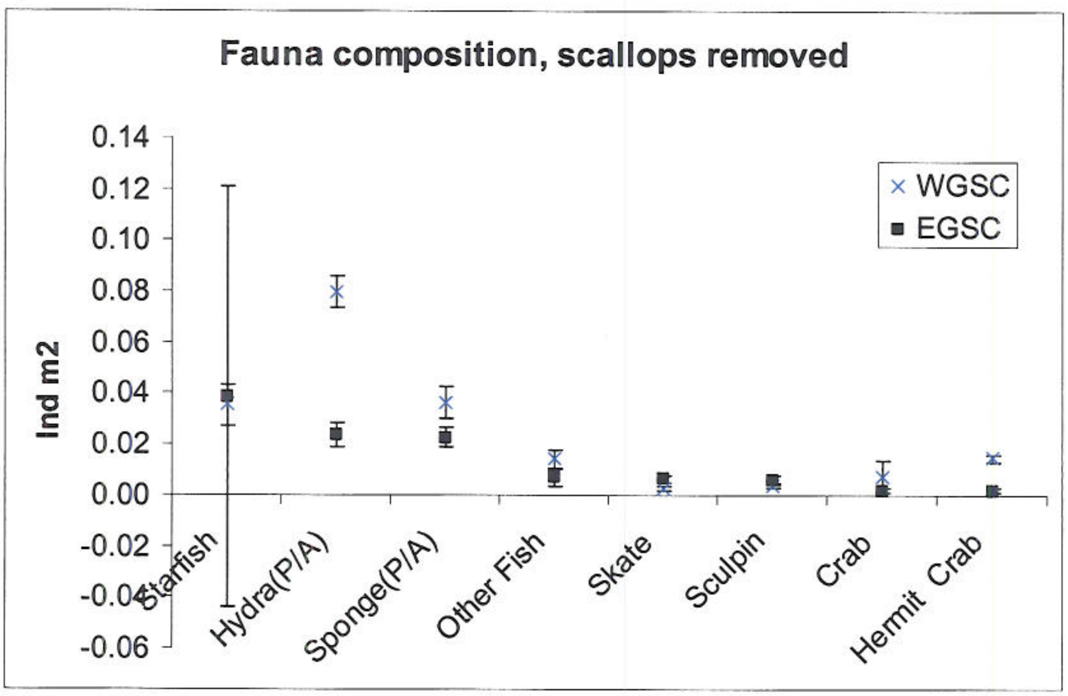

Evaluation

Benefits and contributions to management decision making: This is ongoing research. Sea floor habitat information is fundamental to the designation of Marine Protected Areas (MPA), Habitat Area of Particular Concern (HAPC), and Essential Fish Habitat (EFH). Recently, the New England Fisheries Management Council (NEFMC) developed Amendments 10 and 13 for sea scallop and groundfish management, respectively. Both of these management plans contain a series of habitat alternatives to protect EFH.

The conclusions from these preliminary analyses of the data collected under this research grant have direct implications on the habitat analysis presented in Amendment 10. The analysis of different management alternatives the Great South Channel, based on the USGS Poppe et al. 1989 data, is probably erroneous. These analyses included the figures from 6-93 to 6-101 and the sediment analysis examining the distribution of sediment types within area closure alternatives, pages 7-119 to 7-121 of Amendment 10. Further the overall assumption that granule/pebble substrate indicates high densities of scallops is also false in certain areas. Therefore, the analysis of percentages of sediment found on pages 6-84 (Table 76) is erroneous for the Great South Channel and perhaps other areas of Georges Bank and the mid-Atlantic.

In addition, the Habitat EFH Omnibus Amendment, presently being developed by the NEFMC, relies heavily on substrate information. The maps of substrate and macroinvertebrates generated from these surveys will be presented to the NEFMC Habitat Technical Team. This research has direct implications for scallop stock assessment, habitat impact reduction, rotational management and the Habitat Omnibus Amendment under consideration by the NEFMC. Further the video key may be useful to other researchers interested in identifying benthic fish and invertebrates using video techniques.

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